

CHEMICALS

Project Fact Sheet



PHOTOCATALYTIC MEMBRANES FOR PRODUCING ULTRAPURE WATER

BENEFITS

- Increases the efficiency and cost-effectiveness of reducing total organic carbon in ultrapure water (UPW)
- Achieves a ten-fold reduction in capital expenditure
- Decreases operating power requirements by 96 percent
- Substantially reduces installation cost and increases water treatment rates of traditional photolysing units
- Reuses spent recycle water
- Removes trihalomethanes
- Extends the life of boiler tubes in high-pressure boilers and reduces the need for scheduled maintenance

APPLICATIONS

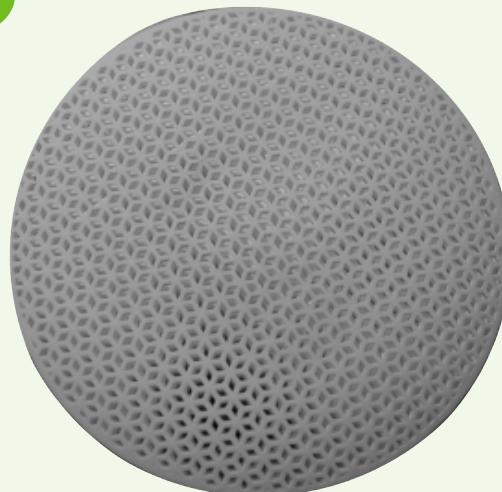
Photocatalytic oxidation for producing UPW has direct applications in several industries. These include UPW for the semiconductor industry, and process water for the pharmaceutical, biotechnology, and power industries. In addition, UPW can supply point-of-use, bottled, and soft drink water. In the pharmaceutical industry, UPW is required for manufacturing, water injection, and as sterile water for inhalation or medical irrigation. In the power industry, UPW is required for use in high-pressure boilers.

NOVEL MEMBRANE INCREASES PRODUCTION EFFICIENCY FOR ULTRAPURE WATER WHILE REDUCING CONTAMINANTS

Ultrapure water (UPW) is an integral component of semiconductor fabrication. The construction of fifty new semiconductor plants in the U.S. over the past six years has increased demand for UPW to three million gallons per day. Specifications are exceedingly stringent for UPW, which is used as rinse water to manufacture next-generation microchips. UPW with total organic carbon (TOC) levels of less than one part per billion (ppb) is required in order to maintain high yields with finer and more complex microchip patterns. Current UPW treatment systems incorporate ultra-violet (UV) light systems to reduce TOC. UV treatment, known as photolysis, is essential for killing bacteria and other microorganisms present in the water. It also produces extremely oxidizing free hydroxyl radicals that reduce TOC to the two to five ppb range. However, UV photolysing is only able to reduce TOC in the first millimeter of water penetrated by the UV light. To address this limitation, project partners are developing photocatalytic oxidation membranes in ceramic modules that can be illuminated with UV light and inserted into existing UPW systems to reduce TOC levels to current and future specifications.

The photocatalytic membrane, when illuminated, promotes oxidation-reduction processes at its surface. These processes generate the hydroxyl radical and lysis products needed to oxidize carbon, thereby reducing TOC and eliminating microorganisms throughout the ceramic body. The semi-transparency of the ceramic membrane allows photons to activate the photocatalyst throughout the ceramic body. Proper photocatalytic module design and operation can produce UPW with less than one ppb of TOC at a substantially reduced cost.

SUPPORT MEMBRANE



Photocatalytic oxidation support membrane, fabricated via stereolithography.



Project Description

Goal: The goal of this project is to design and build a pilot-scale (five to ten gallons per minute) photocatalytic reactor that consistently achieves total organic carbon (TOC) levels of less than one part per billion (ppb) during field-testing in an ultrapure water (UPW) system.

Photocatalytic membrane technology utilizes a titanium dioxide (TiO_2) photocatalyst that is very efficient at producing hydroxyl free radicals when exposed to UV light. The TiO_2 photocatalyst is applied as a membrane layer to a three-dimensional open support structure. The support provides a volumetric distribution of the catalyst and a very high degree of contact between the TOC in the fluid stream and the photocatalytic TiO_2 surface. The technology utilizes stereolithography to build open-pore structures that are tailored to optimize UV penetration depth and fluid flow characteristics to enhance mass transfer rates, resulting in higher TOC destruction.

Progress and Milestones

Early-stage research successfully demonstrated the feasibility of the photocatalyst to achieve sub-ppb TOC levels. Specific achievements include:

- Determined that nanoparticulate and titania sol-based coating methods give high photocatalytic activity
- Demonstrated good adhesion of the nano-particle/sol-based coating methods and showed that photocatalytic activity remained virtually constant after 41 hours of water treatment
- Demonstrated that reticulated substrates offer significant destruction rate improvement over flat disk substrates. Showed higher ppi (pores per inch) foams gave faster TOC reduction
- Proved that the addition of photocatalysis to photolysing and ion exchange treatment enables reduction of TOC to less than one ppb

Current research is focused on achieving the following milestones:

- Determine the optimal membrane design to create good mass transfer and allow UV light penetration
- Refine the TiO_2 application method to ensure sustained catalytic reactivity and durability against erosion
- Design, build and evaluate a pilot-scale operation and field test at selected semiconductor UPW plants
- Show capital and operating costs are at least a factor of ten lower than current photolysing treatment methods

Commercialization

The photocatalytic membrane technology will be developed by Technology Assessment and Transfer and commercialized through Titan Technologies, a company with extensive experience in the field of ultrapure water treatment. Titan has developed strong relationships with potential customers, especially Fluid Lines Inc., an existing supplier of ultrapure water for the semiconductor industry.



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